PL-3.3

Exploiting the versatility of nanostructured transistors for biosensing applications

Bergoi Ibarlucea
Institute for Materials Science and Max Bergmann Center for Biomaterials, Center for advancing electronics Dresden (Cfaed), Technical University of Dresden, Dresden, Germany

Rapid demographic changes demand improved biomedical diagnostic technologies with rapidness, low cost and high-throughput, without sacrificing the sensitivity. Considering the miniature size, scalability of fabrication, and ease of chemical modification, nanoscale ion-sensitive fieldeffect transistors (FETs) packaged in small chips and integrated with additional circuits and lab-on-a-chip structures are ideal candidates to fulfill the task. In this talk, I will give an overview of the advances that we have achieved in this direction, showing a variety of technologies and solutions for different applications. On one hand, we have demonstrated the validity of honeycomb-shaped nanowires as sensor material of FETs for microorganism monitoring activity and screening of antibiotic effects[1]. While traditional approaches rely on optical techniques to measure cell growth, it is rather difficult to distinguish between certain bacteriostatic or bactericide agents. We demonstrate how an electrical-based detection of cell metabolic activity can help to tackle this drawback, by measuring the acidification caused by bacteria that are still alive despite the absence of growth upon bacteriostatic treatment. The analysis of the cells' response under various conditions opens the way to perform optics-less minimum inhibitory concentration assays. On the other hand, we have shown high sensitivity in disease diagnostics[2-3], giving steps toward multiplexing of a variety of pathogens in pico- and femtomolar levels. Integration of different sensors on a single chip can be critical to discriminate rapidly the presence of a specific lethal disease showing similar initial symptoms to others. While the most common FET measurement technique during target molecule attachment is based on the shift of the threshold voltage, recently new alternative methodologies have been demonstrated. I will show the relation of memory properties, e.g. memristive properties[4] and gating hysteresis[5], to the presence of attached biomolecules on the dielectric surface. Additionally, I will discuss the integration of microfluidics offering compartmentalization[6]. Encapsulating enzymes in nanoliter droplets enables the electrical monitoring of hundreds of chemical reactions, critical for high throughput analysis increasing statistics and parallelizing the experiments in a tiny space. Finally, the transfer of nanomaterials to flexible supports by very simple and lowcost techniques will be shown. Bottom-up grown silicon nanowires can be transferred to alternative substrates like plastic foils by a parallel contact printing technique[2], while more hydrophobic materials such as MoS_2 form thin layers on a water tank that remain on the surface after an evaporation process, forming large area sensors[7]. The resulting sensors withstand further mechanical stress than that needed for external body measurements, envisioning their use in wearable devices and smart skins.

References

1. Ibarlucea, B. et al. (2017) Nanowire sensors monitor bacterial growth kinetics and response to antibiotics. Lab Chip 17:4283-4293
2. D. Karnaushenko, B. Ibarlucea et al. (2015) Light Weight and Flexible High-Performance Diagnostic Platform. Adv. Health. Mater. 4:1517-1525
3. B. Ibarlucea et al. (2018) Lethal Disease Discrimination Using Silicon Nanowire-Based Field-Effect Transistors. Proc. 17th IMCS 182-183
4. B. Ibarlucea et al. (2018) Ultrasensitive detection of Ebola matrix protein in a memristor mode. Nano Research 11:1057-1068.
5. B. Ibarlucea et al. (2018) Gating hysteresis as an indicator for silicon nanowire FET biosensors. Appl. Sci 8:950
6. J. Schütt, B. Ibarlucea et al. (2016) Compact nanowire sensors probe microdroplets. Nano Lett. 16:4991–5000
7. P. Zhang, S. Yang, R. Pineda-Gómez, B. Ibarlucea et al. (2019), Electrochemically Exfoliated High-Quality 2H-MoS2 for Multiflake Thin Film Flexible Biosensors. Small 15: 1901265